

# Challenges and Lessons Learned from the Development of Standard Protocols for the Evaluation of Ballast Water Treatment Systems

Richard A. Everett  
U.S. Coast Guard  
Environmental Standards Division (CG-5224)

California State Lands Commission  
Prevention First Conference  
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United States  
Coast Guard



# Developing Test Procedures

(One Person's In-Progress Perspective)

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# Lessons Learned

- Run like h...
- Make useful friends
- Trust but verify
- Don't bust your @\$@ if you can burn some gas
- Don't color outside the lines
- Ignore the chatter (politicians and press)
- Its not a horse race
- More \$\$ = More lawyers
- Murphy!

# Outline

- U.S. Coast Guard authority
- Higher level requirements
- Key partnerships
- Integrated procedures
- Validation
- Harmonization

# USCG interest in testing BW treatment systems

- USCG authorized by Congress to approve BWM methods
  - NANPCA 90/NISA 96
    - Sec 1101 (b)(2)(B)(iii) and (c)(2)(D)(iii)
    - “...if the Secretary determines that such alternative methods are at least as effective as ballast water exchange...”
- Need to develop procedures by which to assess efficacy

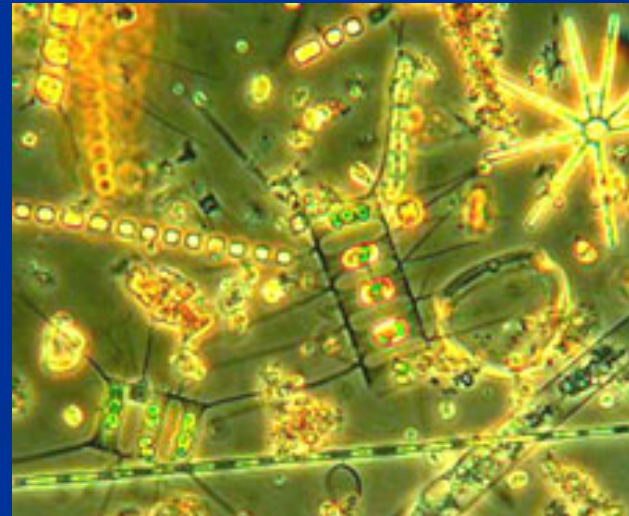
# USCG Approval of Equipment

- 46 CFR 159 (Subchapter Q)
  - Approval of Equipment and Materials
    - Application requirements
    - Application review procedures
    - Test Requirements
      - Efficacy
      - Design, materials and construction appropriate for shipboard
      - Environmental tests
        - Vibration
        - Heat & Humidity
        - Incline
        - Other, as appropriate for equipment and use
  - Independent laboratories
    - Recognition by USCG
      - Qualifications

# Ballast Water Treatment

## General Requirements

- Effective for full range of organisms including
  - Bacteria (0.2 -2  $\mu\text{m}$ )
  - Large Plankton (200  $\mu\text{m}$  - 20 mm)
  - All life stages
  - Sexual and asexual
  - Aerobic and anaerobic
- Effective under wide range of conditions
  - Salinity
  - Turbidity
  - Organic content (Particulate and dissolved)



# Approving BWM Systems

- Type Approval of systems
  - Rigorous land-based tests
  - Shipboard performance assessments
- Requires standard test protocols and methods
  - validated methods and apparatuses
  - controlled and repeatable conditions.
- Results need to be
  - Comparable between tests
    - different treatment equipment at same location
    - different test facilities
  - Scientifically rigorous
  - Legally defensible



# That's it for “Approval”

(in this talk)

- Requirements for approval of ballast water management systems will be part of published regulations.
  - APA: No ex parte communication prior to publication
- Comments today will focus on generic assessment of efficacy / performance
  - Ideally, stakeholders would be interested in high quality credible data on performance

# How Effective?

- Back in the day...
  - Numerous independent efforts to develop BWMS
  - Wide range of testing approaches and metrics
    - USCG R&D Center 2002 evaluation:
      - Testing efforts inadequate
        - Design
        - Methods
        - Documentation
- Independent of “approval” – need to identify appropriate procedures
  - Understand state of technology
  - Identify areas for improvement

# Partnerships

## EPA Environmental Technology Verification Program



United States  
Coast Guard



NSF International

Battelle

Coastal Resource and  
Environmental Management

NRL Center for Corrosion  
Science and Engineering



# Lesson

Make useful friends...and then use\* them

\* Well, actually...work 'em like galley slaves...

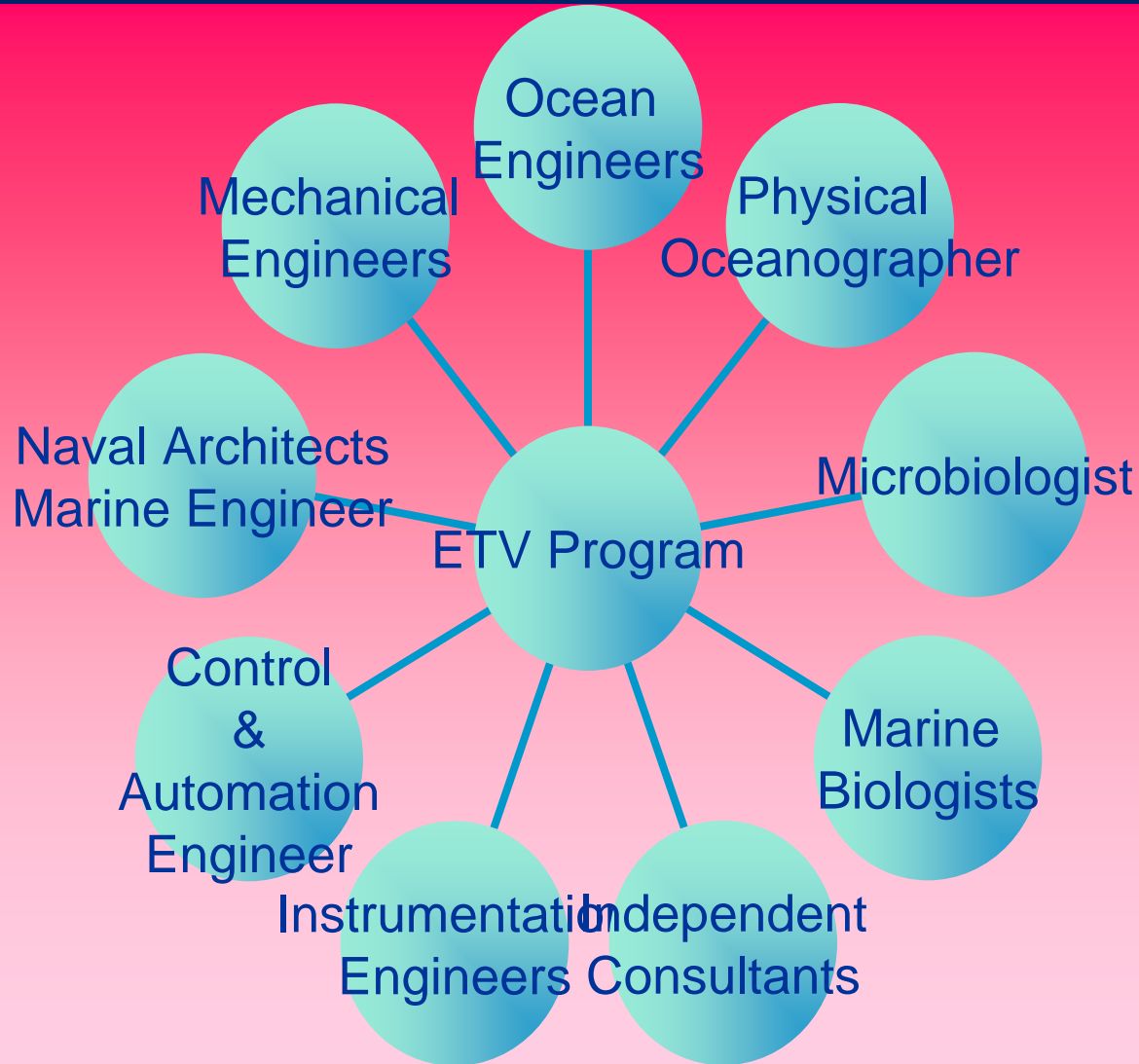
ETV: “The Usual Suspects” A key cadre of technical experts willing to work week ends for little more than food, coffee, and the chance to enjoy the adventure and romance of travel...on federal per diem....

# USCG-EPA Partnership

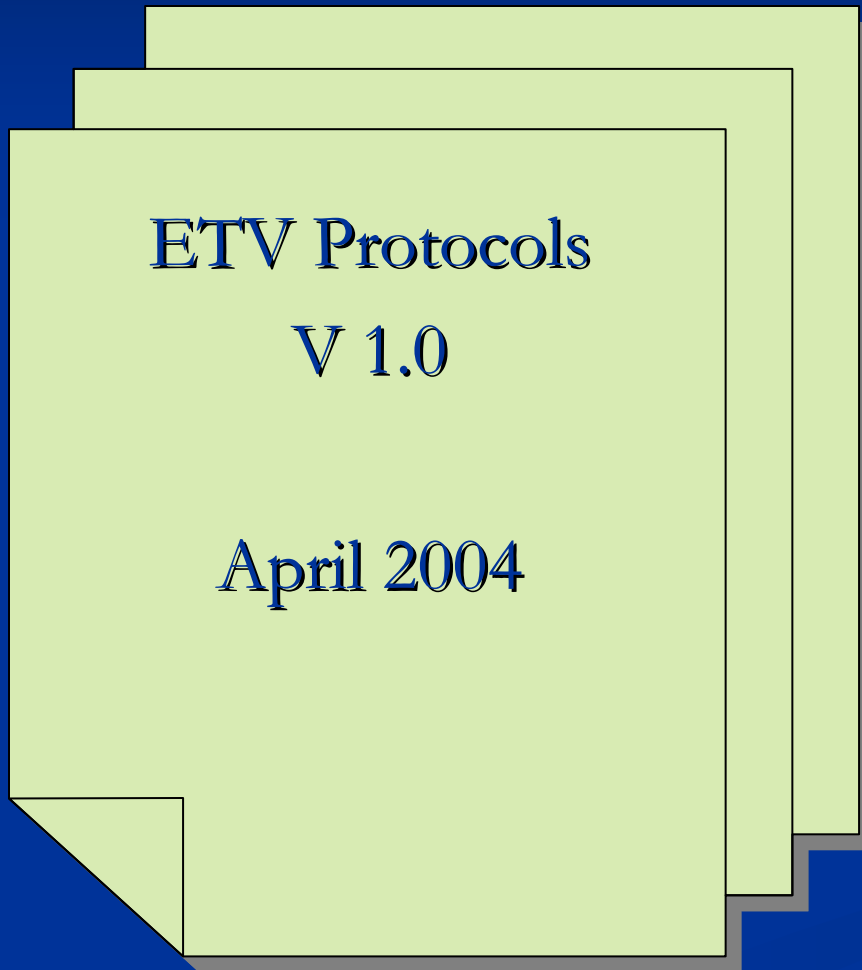
## Testing Ballast Water Treatment Systems

- Environmental Technology Verification Program ( ETV)
  - USCG-EPA MOU 2002
  - Develop Standardized Test Protocols
    - Transparent procedures
    - Rigorous tests
    - Credible results

# ETV Tech Panel



# Draft Testing Protocols



- ❑ ETV Technical Panel & Battelle produced draft protocols in April 2004

- ❑ BPJ

- ❑ Fairly high level guidance

- ❑ Not validated

# Lesson #

Trust, but Validate

Or

Show me the Data...

(...and the methods, the statistical models, the assumptions, the QA/QC procedures, etc)



# A side note on the importance of validation



IMO Guidelines for Approval of Ballast Water Management Systems (G8)

Draft ETV Protocol used as a model

Consensus document

Science & Engineering

International politics

Short time-line

Unvalidated after adoption

Problems with rec's

Ad hoc adjustments

Great Uncertainty

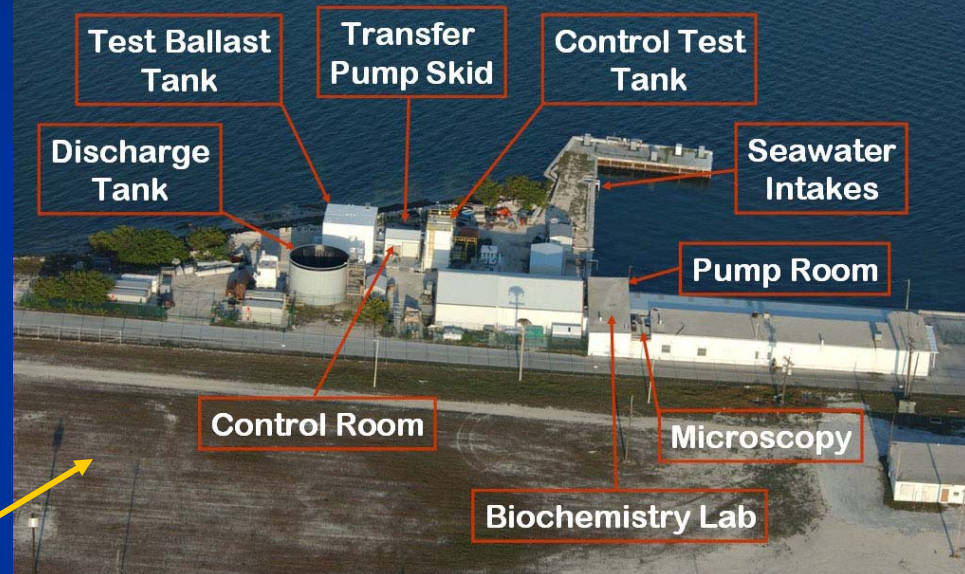
# Validation

- **USCG Broad Area Announcement**
  - Interest/ability/capacity?
- **USCG and NRL Interagency Agreement**
  - **NRL**
    - Long history of ballast tank/system work
    - Significant physical infrastructure
    - Experienced in T&E of shipboard systems
- **Task: Validate ETV Protocol**
  - Independent review of document
  - Model test pad
  - Pilot test

# Pilot BW Treatment Test Facility



Ballast Water Treatment Test Facility at NRL Key West



Center for Corrosion Science & Engineering  
Naval Research Laboratory  
Key West, FL





# Test Facility Components

Pumps

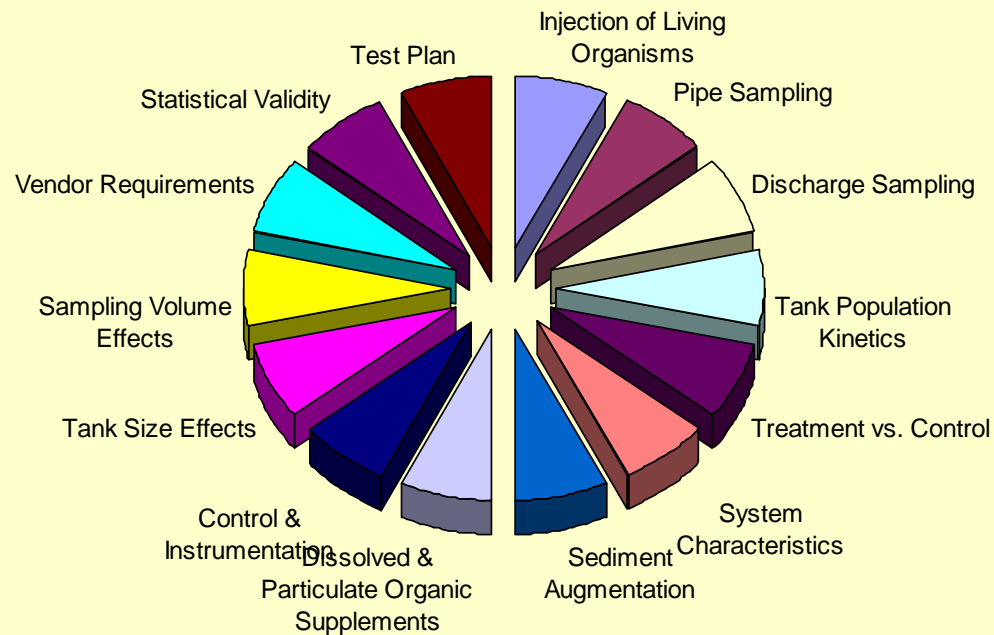


Tanks



Test Pad

# Validation of protocols requires solving many challenging problems



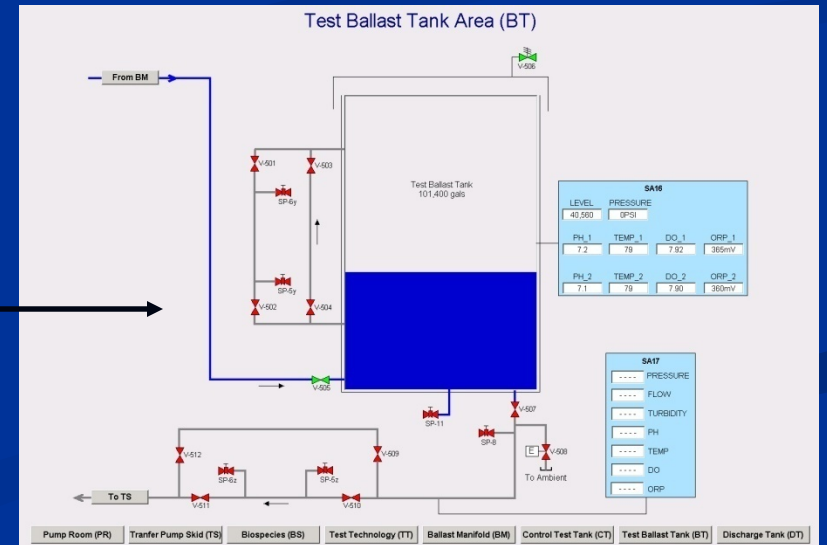
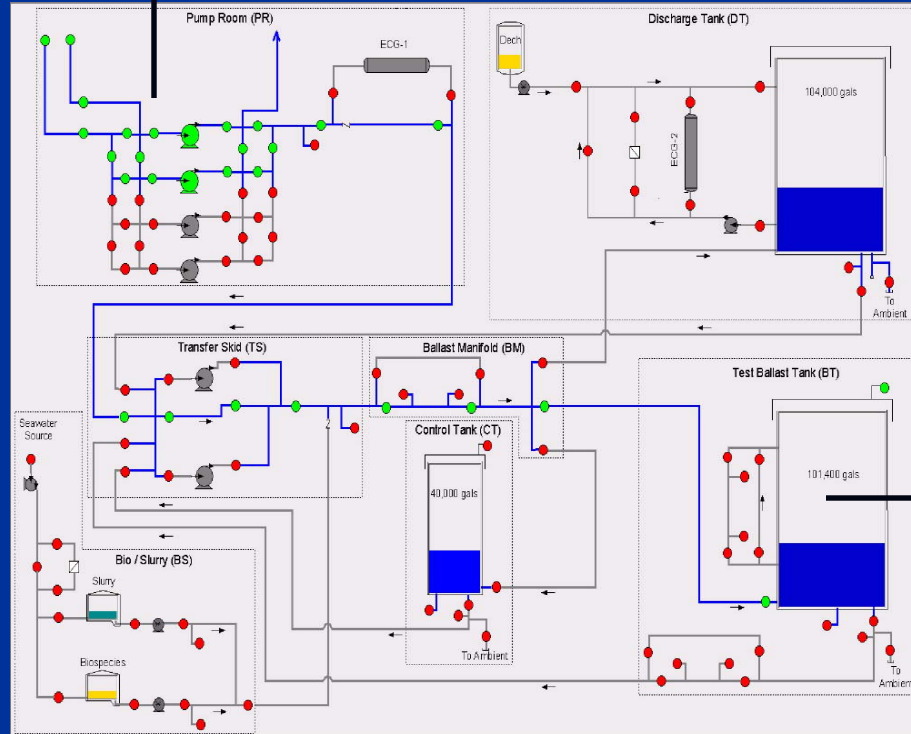
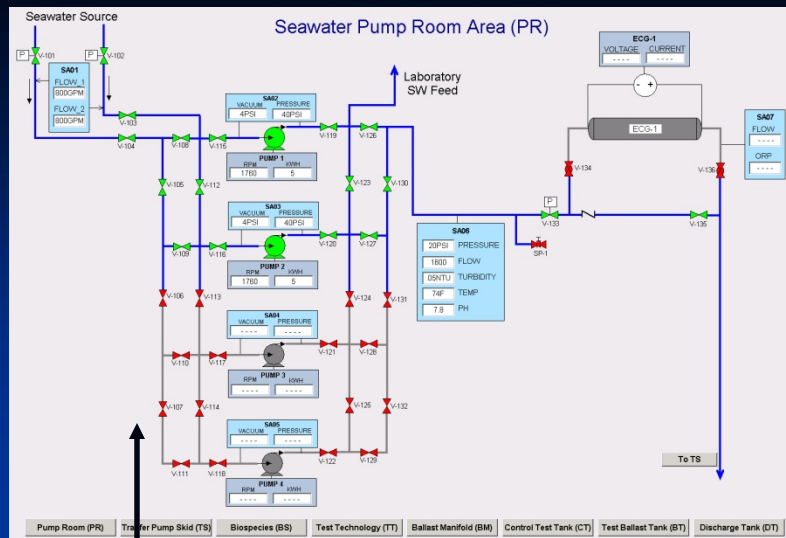
Fundamental questions and challenges  
regarding “HOW-TO” perform testing

# Process Control

- Control and automation essential
  - Consistency, reliability and economy
  - Scientifically defensible
- Approach: industrial process control system
  - Simultaneous operation and feedback control
    - valves, pumps and sensors
  - Data acquisition and archiving
  - Automated data analysis and reduction
  - Alarm conditions for operation outside of specifications
    - Facility
    - BWT manufacturer
- High degree of control
  - Guaranteed operating conditions
  - Verifiable record
  - Reduced human error
  - Reduced induced-organism mortality at sampling locations.







# Instrumentation

- Over 100 instrumented sensors.
  - Flow rate
  - Pressure & Differential Pressure
  - Temperature
  - Dissolved Oxygen
  - Turbidity (NTU)
  - pH
  - Particle Counts & Size Distribution
- 96 valves
  - Flow rate control
  - Isolation & Flow distribution
  - Sample acquisition
  - Most pneumatic and electrically actuated
  - Manual valves wired with a magneto-sensor for open/closed information and supervisory monitoring (QA/QC purposes)
- Sample acquisition ports pre-BWT, post-BWT, post-tank
  - Organisms
  - Chlorophyll, POC, DOC, CHNP



# Lesson

Don't bust...

Or

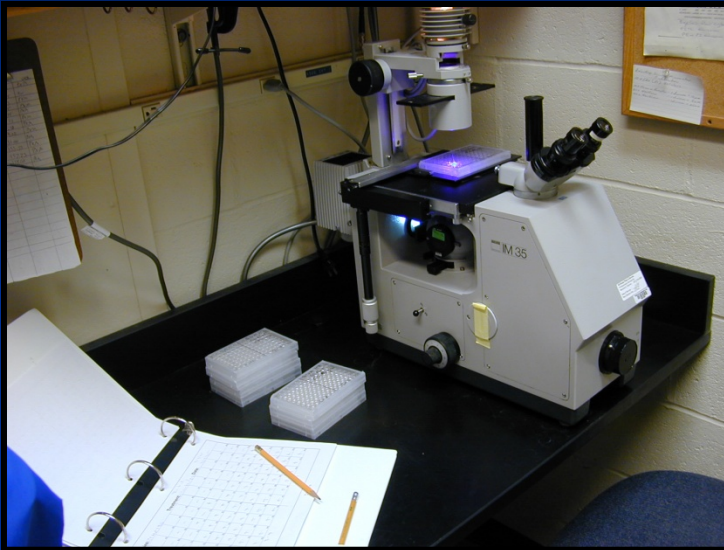
Let the electrons work the 14 hour days...

...but keep some smart people around...

...and **VALIDATE**

# Automation: Rapid and Consistent Analysis

The expert at the 'scope is neither sustainable nor desirable



Counting and Classifying 300 Zooplankton Organisms As Dead or Alive Takes (Poke Method) a Human Operator at Least 3.5 Hours.

Very Difficult to Maintain Observational Consistency

Sample Degradation within 6 hours

Automation results:

- Greatly reduced analysis time

- Image and Video Archive

- Cost Over Time is Less - Fewer Technicians



# Automation of Sample Analysis

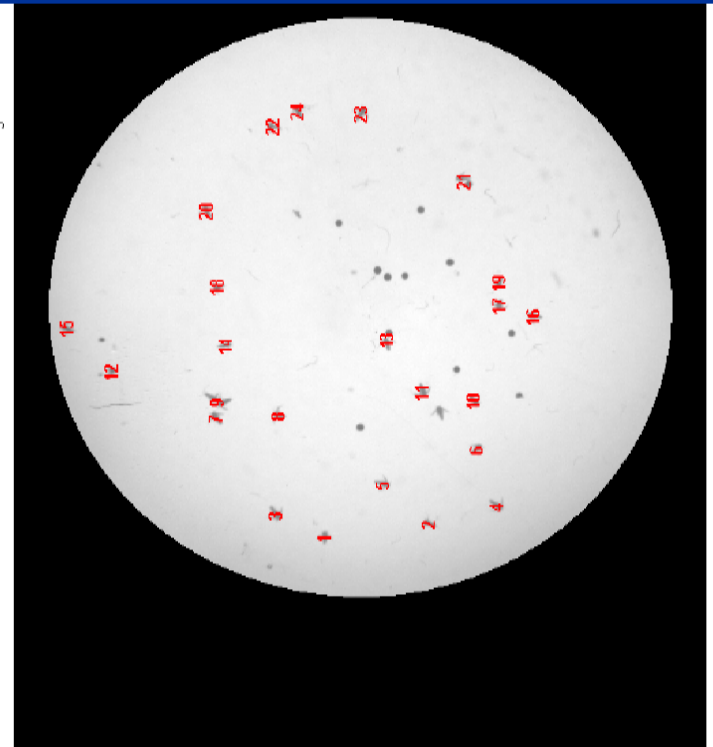
- FlowCAM by Fluid Imaging Technologies Inc.\*

- 1  $\mu\text{m}$  to 3 mm optical flow cytometer



- In-house Image Analysis
- Larger plankton

Total Artemia = 25 Number of Potential Dead Artemia = 24 Image #1



\*Not an endorsement!

# Automated Sample Analysis

## Initial Results

- Data Archive
  - Particularly image files
- Reduced time
- Increased consistency
- Reduced cost (eventually...)

# Consistency and Comparability

- Harmonization is critical among test organizations/facilities
  - Domestic
    - NRL Key West FL
    - GSI Superior WI
    - MERC Baltimore MD
    - PNNL Sequim WA
  - International
    - NIVA Norway
    - NIOZ Netherlands
    - Korea?
    - Japan?
    - South Africa?

# Lesson

Don't color outside the lines

Or

Standardization, comparability, and consistency are  
critical

# Comparability and Consistency Paramount

- Test rigor and QA/QC need to be comparable across tests
  - Within sites
  - Across sites
- Significant variability will hurt
  - Buyers need to know system will perform as needed
    - Certificate alone not enough
      - Approved systems may be required (IMO, U.S.?)
      - Discharge standard may also apply (IMO, CA, U.S.?)
  - Regulatory agencies need to have confidence

\* Based on pending legislation

# Achieving Consistency and Comparability

## ■ Standard procedures

- Validation

## ■ Intersite “calibration”

- Analytic methods
  - Spiked blind samples
- Site comparisons
  - Parallel tests

## ■ Transparency

- Public reports
  - Results
  - Methods

## ■ Standard Test Organisms

### ■ Pros

- Common biological link between tests
- Eventually – simplification of analyses??

### ■ Cons

- Added complexity
  - Culturing, injection, stock consistency
- NIS concerns



# Things to Consider

- Process control and automated analysis are paramount.
  - Production time scales
  - Large quantities
  - High statistical confidence and rigor
  - High quality assurance
- Surrogate identification & optimization work required.
  - Comparability among tests...
  - Significant drawbacks
- Multiple test sites are likely necessary for reliable and consistent testing in the future.
  - Test facility designs and procedures require validation
  - Need to ensure a satisfactory level of inter-site comparability





<http://www.uscg.mil/hq/g-m/mso/estandards.htm>